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POWER FACTOR IMPROVEMENT

ASHOK KUMAR

Associate Professor, Dr. K. N. Modi. Institute of Engineering & Technology, Modinagar, Uttar Pradesh, India

ABSTRACT

Power factor has play an important role in electrical engineering i.e. in Generation, Transmission and distribution of Electrical Energy and Electrical machinery section also.In this article it will be discussed, the power factor comes down and now effect in due all electrical systems.

It is common practice by the companies to charge plantation to consumers who fall below the set due specified value of power factor. For large Industrial consumers this might be a meaning of huge financial impact. Hence, electrical managers, engineers always keep a special eye on the operating condition of power factor and try to compensate it with appropriate sized (values) capacitors installed.

KEYWORDS: Power Factor, Active Power, Reactive Power, Capacitor, Resistance, Inductors

INTRODUCTION

The nature and value of power factor is totally depends upon the type of electrical load. it may be unity, lagging, leading Electrical load may me resistive, capacitive and Inductive which decide the nature of power factor. An ideal case of power factor has to be 1.0 (Unity), it is practically not possible to equal real power to apparent power factor, at practical ground the equipments operates at a power factor of 0.9 to 0.95.

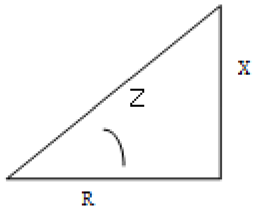
In this article, meaning of power factor, advantage, Disadvantage of p.f. and how it is improved will be widely discussed.

Meaning of Power Factor

Power factor may be defined in three ways as discussed below:

- Theoretically, power factor may be defined as the cosine angle between voltage and current waves.
- Mathematically power factor may be defined as the ratio of resistance to impedance for electrical circuit's.
- I.e Power factor = $\frac{R}{Z}$

Where power factor = cos ¢



R = Resistance in ohms

Z = Impedance in ohms. R

Let z = (R + j X)

From Triangle

cos ¢= R/Z

Z = Impedance

R = Resistance

X = Reactance may be inductive.reactance (X_L), capacitive reactance (X_C) or may be combination of both (X_L & X_C)

- Power factor may be defined as due ratio of real power to the apparent power.

Power factor = cos ¢ = active power/apparent power

Let S = P + jQ

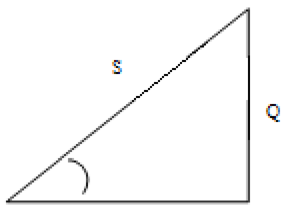
Where S = apparent power =3 Vp I_p

For there phase system

P = 3 V_p I_p cos ¢– measured in terms of W or KW or MW

Q = 3 V_p I_p sin ¢– expressed in terms of KVAR or MVAR

From power equation, makes a triangle.



cos ¢ = power factor = $\frac{R}{Z} = \frac{KW}{KVA}$

"NATURE OF POWER FACTOR"

The nature of power factor may be unity, lagging and leading, discussed below one by one.

Unity P. F.

If due electrical load is purely resistance then the P.F. will be unity, because in the case there is no phase angle between voltage and currect means both lies on the same reference

Phase or Diagram

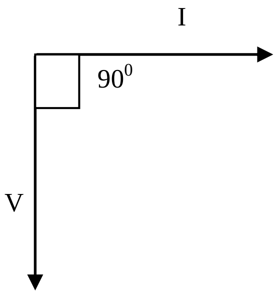
V.I

Wave diagram

Lagging P.F.

If due electrical load is inductive type then the nature of power factor will be lagging, because in this case current lags the voltage by 90^0.

This can be understand with the help of phase and wave diagram.



For industrial load

$I = I_m \sin (wt - 90^0)$

$V = V_m \sin wt.$

LEADING P.F.

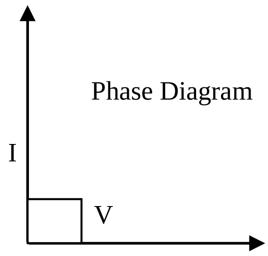
If due electrical load is capacitive, then due power factor will be leading pf because is this case, current leads the voltage by 90^0, it can be easily understand with due help of phase and wave diagrams.

For purely capacitor circuit

I leads V by 90^0,

So, $I = I_m.\sin (wt + 90^0)$

$V = V_m. \sin wt$



Phase Diagram

"NEED OF POWER FACTOR IMPROVEMENT"

The need of power factor improvement is very important, to the understand the importance of power factor is electrical system. "It is requires to maximize active power delivered by the system and minimize the other type of power. as we said treat we want to maximize admittance and minimize reactive power. It should be clear from the mathematical relation among the power factor, active and apparent power, requires a task, power factor must be close to unity as possible, but it is not possible in practically, in actual electrical system due to presence of inductance and capacitances of the system.

For example, our transmission lines have both inductance and capacitance and we have to use techniques to bring power factor to desired level. So there is a need of power factor improvement is extremely important.

How P.F. Effected Electrical Machine Action?

P.F. has an important role in electrical machine when machine is under load, machine may be the type of motor (Induction, synchronous and alternator) etc discussed one by one.

Induction Machine

Induction machine always work with lagging power factor. This varies 0.2 lagging to 0.8 lagging. In this field pf is working under lagging mode, because all induction motor, industrial AC machine have inductive load, due to inductive load the power factor will be very low, it draw a large amount of reactive power (KVAR) from supply side.

Synchronous Motor works with unity, lagging & leading P.F. and in this case if the value of power factor is unity, then it is acting under critical excitation, if pf is lagging work under excitation and if the pf is leading then the synchronous motor is working over excitation mode. in three mode the working of syn. motor is changed due to the nature of power factor.

Disadvantage of Low Power Factor

As discussed above the power factor is defined as the ratio of real power (expressed in kw) to apparent power (express in KVA). The real power actually delivered and consumed by the electrical devices. Hence the value of real power, lower will be the P.F.

An idal case of P.F has to be 1.0 (Unity).

It is practically not possible to equal real power to apparent power therefore.

Low Power Factor Has Various Disadvantage Discussed As

- If P.F. is low, then move kva rating and due to this move electric bill paid by the consumer to the company as it is clear from the following relation.

  P.F. $=\frac{Atice\ Power}{Apparent\ Power}=\frac{KW}{KVA}$

  Active Power/ Apparent Power

  KVA $=\frac{KW}{p.f}$ -A

  (KVA = kw/p.f.)

  It is clear from the above equation A if thep.f. is low, KVA will be high, more electric bill be paid.

- If p.f. is low then more transmission line loss:

  Discussed below:P = $\sqrt{3}\ V_L I_L \cos ¢$ – for 3 to system

  $I_L = \frac{P}{\sqrt{3}VL.\cos ¢}$

  It is clear from this relation if p.f. is low then line unit will be high, transfer the line loss will be very high.

- If the power factor is low, the conductor size will be grater.
- If the pf is low, the voltage regulating of electrical system (Trans, Generator, Distribution solution) will be poor.
- If due pf is low, then it reduced the power handling capacity of the system.

Advantage of High Power Factor

There are various advantage of high or improved power factor discussed as below.

- If the power factor is high then KVA rating will be low, then less electric bill will be paid by the consumer to the company. This is clear:-

  p.f. $=\frac{KW}{KVA} \longrightarrow$ KVA $=\frac{KW}{pf}$

  if p.f. is high, then KVA will be low,

- If the p.f. is high, then line current will be low, then the line loss will be low.

  As discussed below:

  $I_L = \frac{P}{\sqrt{3}V.\cos ¢}$

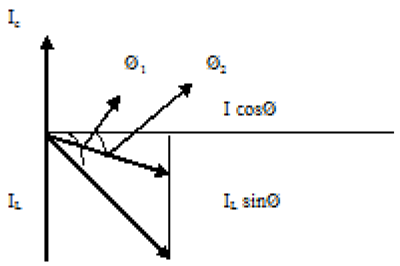
It is clear from above relation if pf is high, then I_L will be low, I^2R will be low.

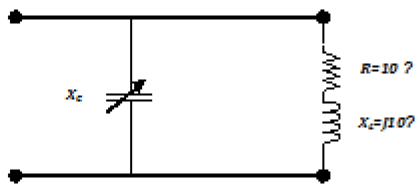
Power Factor Improvement

Usually the power factor is low due to the presence of inductive load, ie AC motors, are lamps, electric discharge lamps. Due to low power factor there are various disadvantages as discussed earlier. So hence thereis a need to improve the power factor to get the advantage of improved power factor.

For this purpose if a capacitor is connected in parallel with electrical load (Series RL circuit). Then the power factor will be improved.

Pf improved can be understand use the help of phasor and circuit diagrams discussed below:





From phasor diagram

$I_L \cos ¢_1 = I \cos ¢_2$

Multiplying by V in both side

$VI_L \cos ¢_1 = VI \cos ¢_2$

From phase diagram. After connect a capacitor across due load (In paralled). Reactive components is reduced but active component is constant (wattfal competent). Therefore fromphasor diagram

$¢_{2<} ¢_1$ but $\cos ¢_2 > \cos ¢_1$

Hence the power factor has been improved after connect capacitor.

P.F has been improved, it can be seen mathematically, after verification the value of capacitor discussed below by

Variousexample.

In theseexamples all values has been taken in terms of ohms (R_1,X_L,X_C) and the value $X_C$will be vary

- R = 10 ohmsfixed value

  X_L = J10 ohms

  $X_c = J.25\ ohms$

  $Z = (10 + J10) ohms = 14.14\angle 45$

  $Z = \dfrac{14.14\angle 45^0 \quad x.25\angle \quad 90^0}{(10+j10-j.25)}$

  $Z = \dfrac{14.14x.25\angle -45^0}{(10+j9.25)} = \dfrac{14.14x.25\angle -45^0}{13.622\angle 42.76}$

$$Z = \frac{3.535\angle -45}{13.622\angle 42.76} = 0.259\angle -87.76$$

$Z = 1ZIØ = 0.259\angle -87.76$

p.f =cos (-87.76) = 0.039

- R = 10 ohmsfixed value

  X_L = J10 ohms

  X_c = - j.5ohm $\quad Z = \dfrac{14.14\angle 45 \text{ x } .5\angle -90^0}{(10+j10 - j.5)} = 0.512\angle -88.53$

  $$Z = \frac{7.07\angle -45}{(10+j9.5)} = \frac{7.07\angle 45}{13.75\angle 45\text{-}53}$$

  p.f = cos ¢= cos (- 88.53) = .025

- X_c = j2.5 ohms, Z = (10+j10) ohms

  $$Z = \frac{(10+j10) \text{ x } 2.5\angle -90^0}{10+j10-j2.5} = \frac{14.14\text{x}2.5\angle -45^s}{(10+i7.5)}$$

  $$= \frac{14.14 \text{ x } 2.5\angle -45^0}{12.5\angle 36.86^0} = \frac{35.35\angle -45^0}{12.5\angle 36.86^0}$$

  $Z = 2.828\angle -81.86$

  Cos Ø= cos 81.86 = 0.142

- Xc = J5ohmsZ = $\dfrac{14.14\angle 45^0 \text{ x } 5 \quad \angle -90^0}{(10+j10-j5)}$

  $$Z = \frac{14.14\angle -45^0 \text{ x } 5}{(10+j5)} = \frac{70.7\angle -45^0}{11.18\angle 26.56}$$

  $Z = 6.32\angle 71.56$

  Pf = cos Ø = cos (71.56) = 0.316

- Xc =j10ΩZ = $\dfrac{14.14\angle 45^0 \text{ x } 10\angle -90^0}{(10+J10 - J10)}$

  $$Z = \frac{141.4\angle -45^0}{10\angle 0^0} = 14.14\angle -45^0$$

  PF = cos(-45)= .707

- Xc =j 20 Ω

  $Z = \underline{14.14\angle -45^0 \text{ X } 20\angle -90^0}$

(10+j10 – j20)

$2\angle 0$

$= \underline{28.28}\angle \underline{-45^0} = \underline{28.28 \angle -45} = 2\angle 0$

(10-j10) 14.14 ∟-45

P.F=Cos Ø = cos (0^0)= 1(unity)

Table for Power Factor Improvement

The value of R = 10 Ω, X_L = 10 Ω are fixed but the value of capacitance in terms of capacitive reactance is varied then P.F will be calculate above, calculation, so, the table shows the result if the value of capacitance (or capacitive reactance) is increase then the value of P.F is improved.

Table 1

S. No.	R(Ω)	X_l (Ω)	X_c (Ω)	Total Impedance	Ø	P.F. (Cos Ø)
1.	10	J10	-J0.25	0.259∟-87.76	-87.76	0.039
2.	10	J10	-J0.50	0.512∟-88.53	-88.53	0.025
3.	10	J10	-J2.5	2.828∟-81.86	-81.86	0.142
4.	10	J10	-J5.0	6.32∟-71.56	-71.56	0.316
5.	10	J10	-J10.0	14.14∟-45	-45	0.707
6.	10	J10	-J20.0	2.0∟0	0	1.00

CONCLUSIONS

As per the above discussion, the power factor has an important role in electrical system, it variety the value of action, reaction power etc. If the power factor improved, then there are various advantage to the consumers may commercial, industrial and domestic purposes. In this article main component are resistance, capacitance and inductance but capacitance may be any type has an important role to improve the power factor. It can be study from the table as above show.

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